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Candidate surname

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Other names

**Pearson Edexcel
Level 3 GCE**

Centre Number

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Candidate Number

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Monday 15 June 2020

Morning (Time: 2 hours 30 minutes)

Paper Reference **9BI0/03**

Biology B

Advanced

Paper 3: General and Practical Principles in Biology

You must have:

Scientific calculator, HB pencil, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Show your working in any calculation questions and include units in your answer where appropriate.
- Answer the questions in the spaces provided
– *there may be more space than you need.*
- You may use a scientific calculator.
- In question(s) marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing how the points that you make are related or follow on from each other where appropriate.

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ►

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Answer ALL questions.

Write your answers in the spaces provided.

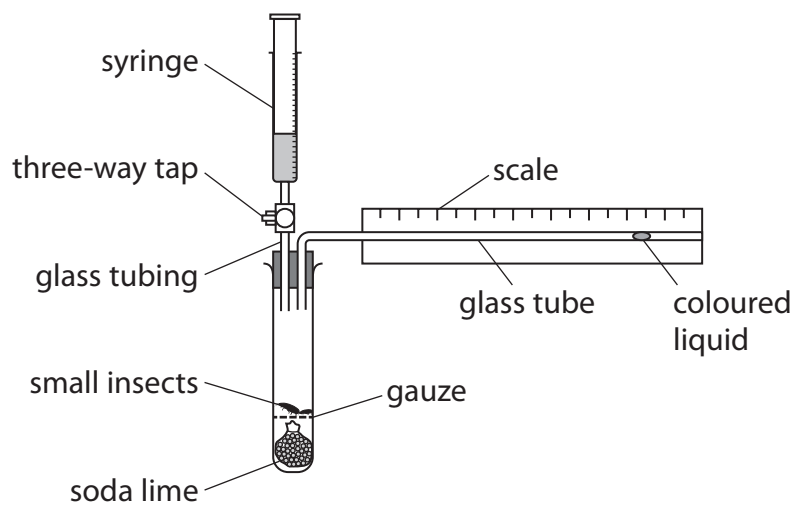
- 1 (a) Describe how oxygen from the air is able to reach insect muscle cells.

(3)

Oxygen enters the insect's body through the spiracles (openings in the exoskeleton), then diffuses along the tracheae and into the tracheoles, which reach the muscle cells, and into the cells, down a concentration gradient, as the muscle cells use oxygen in respiration.

- (b) A respirometer was used to compare the rate of aerobic respiration of two species of insect.

The diagram shows the respirometer.



- (i) Give the units for a valid comparison of the rate of respiration of these two species of insect.

(1)

$\text{mm}^3 \text{ min}^{-1} \text{ g}^{-1}$ (volume of oxygen per minute per gram of insect)



(ii) Other factors may affect the results from this respirometer.

Describe how one named factor could be controlled when using this respirometer. (2)

Temperature: place the respirometer tube in a thermostatically controlled water bath set at a constant temperature (e.g. 25 °C), and leave it to equilibrate before taking readings.

Also use insects of the same size, mass and age for each species, or divide by the mass of the insects.

(iii) Explain why the soda lime in the tube must be replaced when the other species of insect is placed in the respirometer. (2)

The soda lime has already absorbed carbon dioxide from the first species, so it may have absorbed the maximum amount and no more carbon dioxide can be absorbed.

Carbon dioxide released would then replace the oxygen used, so the coloured liquid would not move (or would move less) and the readings would be an underestimate and not valid.

(Total for Question 1 = 8 marks)



2 The egg of a hen contains albumin, a globular protein.

(a) Describe the tertiary structure of a globular protein.

(3)

The polypeptide chain is folded into a compact, spherical (rounded, 3D) shape.

The polar (hydrophilic) R groups are on the outside, so the protein is soluble in water, and the non-polar (hydrophobic) R groups are on the inside.

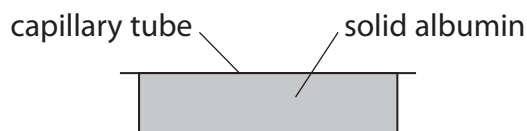
The shape is held by hydrogen bonds, ionic bonds and disulfide bonds (bridges) between R groups.



(b) Pepsin is an enzyme that digests albumin.

Albumin can be put into a 50 mm long capillary tube and then made solid by boiling in water for 10 minutes.

The diagram shows a 50 mm capillary tube containing solid albumin.



Devise an investigation into the effect of pepsin concentration on the digestion of solid albumin.

(5)

Make a range of at least five pepsin concentrations, e.g. 0, 0.2, 0.4, 0.6, 0.8 and 1.0%,

by diluting a stock solution with distilled water; the 0% tube (no enzyme) is the control for comparison.

Use capillary tubes of the same length (50 mm) filled with the same source of albumin, boiled for the same time, and place one tube in the same volume of each pepsin solution.

Control the temperature with a water bath (e.g. 37 °C) and the pH with a buffer (e.g. pH 2).

Leave the tubes for the same time (e.g. 24 hours), then measure the length of albumin remaining (or digested) in each tube with a ruler (or time how long it takes for the albumin to disappear).

Use several capillary tubes at each concentration (repeats), identify anomalies and calculate the mean and standard deviation; plot length digested against pepsin concentration.

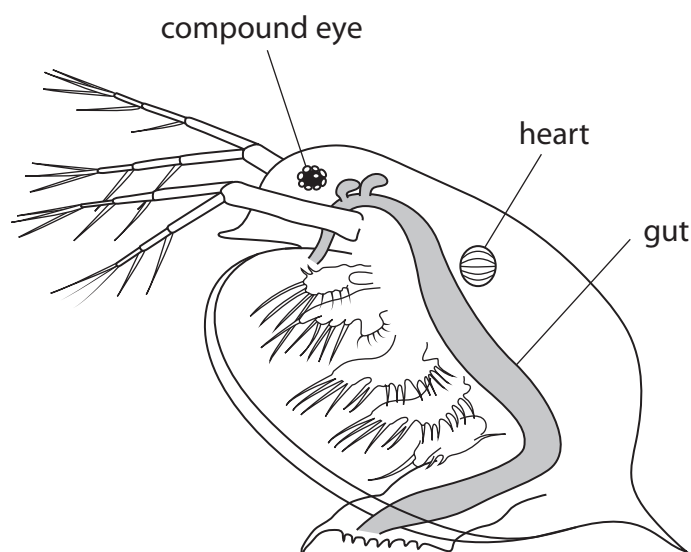
(Total for Question 2 = 8 marks)



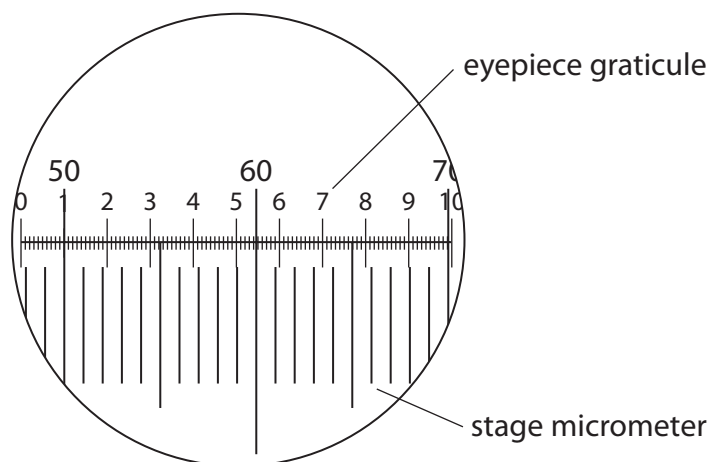
3 Water fleas are small animals that live in pond water.

A student observed a water flea using a light microscope.

The diagram shows the student's drawing of the water flea.



The diagram shows an eyepiece graticule and a stage micrometer used by the student to measure the diameter of the heart in this water flea.



(Source: <http://biology4alevel.blogspot.com/2014/07/2-cell-structure-microscopy.html>)

Each small division on the stage micrometer is 0.01 mm.

The diameter of the heart was found to be 0.2 mm.

(a) Determine the number of eyepiece units that equal the diameter of the water flea heart.

(1)

Answer 9.....



- (b) The water flea has a spherical heart with a diameter of 0.2 mm.

Cardiac output is the volume of blood pumped out of a heart in one minute.

The resting heart rate of a water flea is 200 beats min^{-1} .

The volume of a sphere is calculated using the formula

$$\frac{4}{3} \pi r^3$$

where $\pi = 3.142$

- (i) Calculate the cardiac output of a water flea at rest using the formula

cardiac output = stroke volume $\times$ heart rate

(3)

$$\text{radius} = 0.2 \div 2 = 0.1 \text{ mm}$$

$$\text{stroke volume} = \frac{4}{3} \times 3.142 \times 0.1^3 = 0.004189 \text{ mm}^3$$

$$\text{cardiac output} = 0.004189 \times 200 = 0.8379 \text{ mm}^3 \text{ min}^{-1}$$

$$1 \text{ dm}^3 = 1\,000\,000 \text{ mm}^3$$

$$0.8379 \div 1\,000\,000 = 8.38 \times 10^{-7} \text{ dm}^3 \text{ min}^{-1}$$

Answer 8.38×10^{-7} $\text{dm}^3 \text{ min}^{-1}$

- (ii) The cardiac output of a human heart at rest is $5.0 \text{ dm}^3 \text{ min}^{-1}$.

Give one reason why the cardiac output of a human heart at rest needs to be greater than the cardiac output of a water flea at rest.

(1)

A human has many more cells (a larger body), which all need a supply of oxygen and glucose for respiration.



(c) A student investigated the effect of adrenaline and acetylcholine on the heart rate of water fleas using the following method:

- place a water flea in pond water on a microscope slide
- count the number of heart beats in one minute
- repeat with two other water fleas
- repeat this procedure using three water fleas placed in adrenaline solution and three water fleas placed in acetylcholine solution.

The table shows the results of this investigation.

Treatment	Heart rate / beats min ⁻¹				Standard deviation (SD)
	Water flea 1	Water flea 2	Water flea 3	Mean	
Pond water	195	185	190	190	
Adrenaline solution	240	236	238	238	± 2.0
Acetylcholine solution	116	120	118	118	± 2.0

(i) Calculate the standard deviation for the mean heart rate in the pond water.

Use the formula

$$SD = \sqrt{\frac{\sum (X - \bar{X})^2}{n - 1}}$$

(2)

$$\text{mean} = 190$$

$$(X - \text{mean}): 5, -5, 0 \quad (X - \text{mean})^2: 25, 25, 0$$

$$\sum (X - \text{mean})^2 = 50$$

$$50 \div (3 - 1) = 25$$

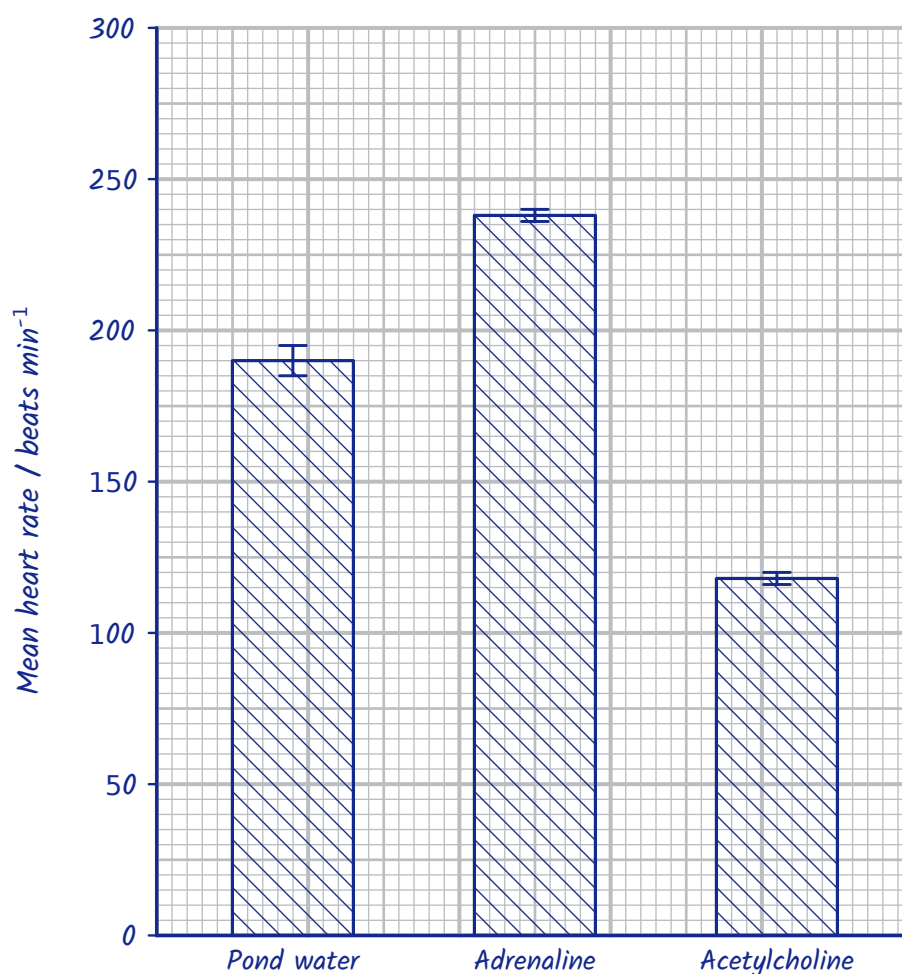
$$SD = \sqrt{25} = 5.0$$

Answer ± 5.0



(ii) Plot a graph to show the data for the mean heart rate and SD in each treatment.

(2)



(iii) Explain why abiotic variables should be controlled in this investigation.

(2)

So that the treatment (adrenaline or acetylcholine) is the only factor affecting heart rate, to give a valid comparison (valid results).

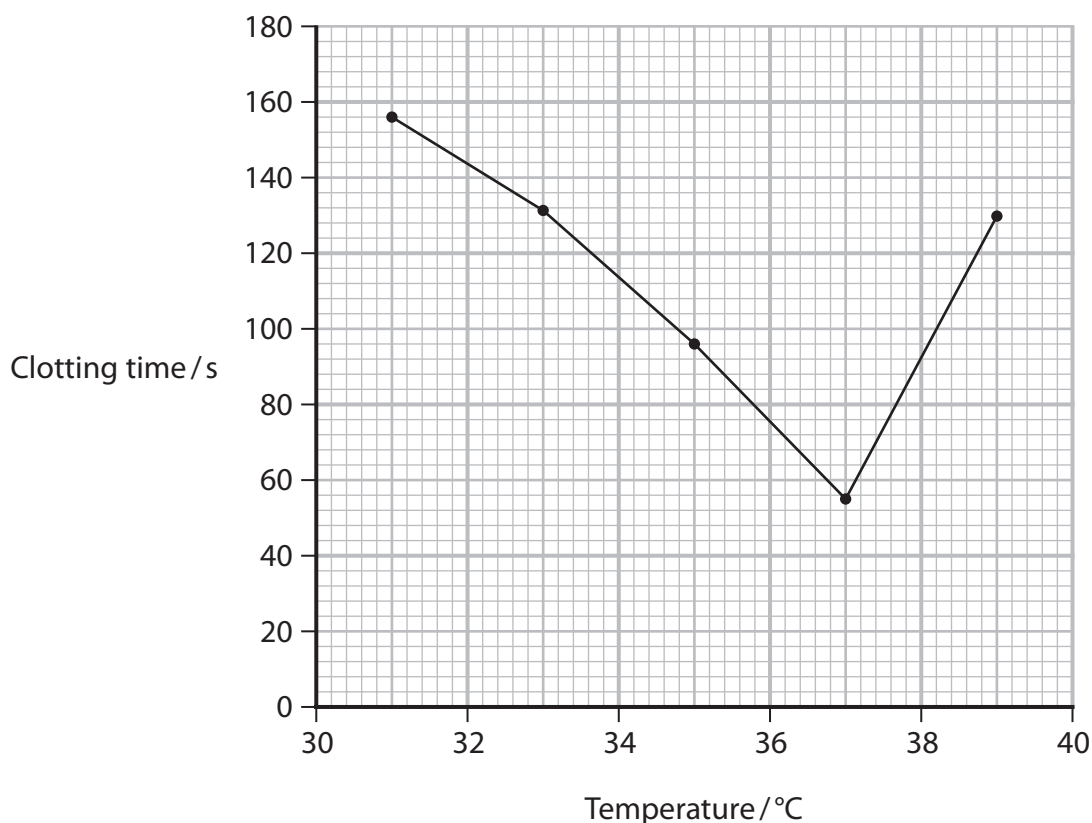
e.g. temperature, because water fleas are ectotherms and temperature affects their heart rate; pH and carbon dioxide concentration also affect heart rate.

(Total for Question 3 = 11 marks)



P 6 2 1 2 7 A 0 9 3 6

- 4 A scientist investigated the effect of temperature on the time it takes for blood to clot. The graph shows the results of this investigation.



- (a) Explain how these results show that enzymes are involved in blood clotting.

(3)

Below 37 °C clotting takes longer at lower temperatures because the enzymes and substrates have less kinetic energy, so there are fewer enzyme-substrate collisions (fewer enzyme-substrate complexes).

Clotting time is shortest (about 55 s) at 37 °C, the optimum (body) temperature for the enzymes.

Above 37 °C clotting takes longer (130 s at 39 °C) because the enzymes are denatured (the active site changes shape).



- (b) Prothrombin is involved in the blood clotting process.

The *F2* gene codes for the synthesis of prothrombin.

This gene is located from base pair 46 719 191 to base pair 46 739 504 on chromosome 11.

Determine the number of codons in this gene.

$$46\,739\,504 - 46\,719\,191 + 1 = 20\,314 \text{ bases; } 20\,314 \div 3 \quad (1)$$

Answer 6771

- (c) A mutation of the *F2* gene causes thrombophilia, a condition that results in the production of excess prothrombin.

In this gene mutation, guanine is replaced with adenine.

- (i) Name this type of mutation.

(1)

Substitution (point mutation)

- (ii) People without this mutation have a 1 in 1000 risk of producing a blood clot in an artery.

The mutation increases this risk by 20 times.

State the probability of producing a blood clot for people with this mutation.

(1)

1 in 50 (0.02 or 2%)

- (iii) Explain why thrombophilia increases the risk of producing a blood clot in an artery.

(3)

Excess prothrombin means more prothrombin is converted to thrombin, so there is more thrombin.

Thrombin is an enzyme that catalyses the conversion of soluble fibrinogen to fibrin, so more fibrin is made.

Fibrin is insoluble and forms a mesh (net) of fibres that traps blood cells (platelets and red blood cells), forming a clot.



(d) A genetic test can be used to find out if a person has thrombophilia.

The test involves using a restriction endonuclease to obtain genetic material from white blood cells.

This genetic material is then used in the polymerase chain reaction (PCR).

(i) State the role of a restriction endonuclease.

(1)

To cut the DNA at specific base sequences (recognition sites) into short fragments (sections of DNA).

(ii) Describe the process of PCR.

(3)

The DNA is mixed with primers, free DNA nucleotides and DNA polymerase (Taq polymerase) in a buffer.

Heat to 95 °C for 30 seconds, to break the hydrogen bonds and separate the DNA strands.

Cool to 55 °C for 20 seconds, so the primers bind (anneal) to the complementary bases at the ends of the single strands.

Heat to 72 °C, so DNA polymerase joins nucleotides to form new complementary strands (replicates the DNA).

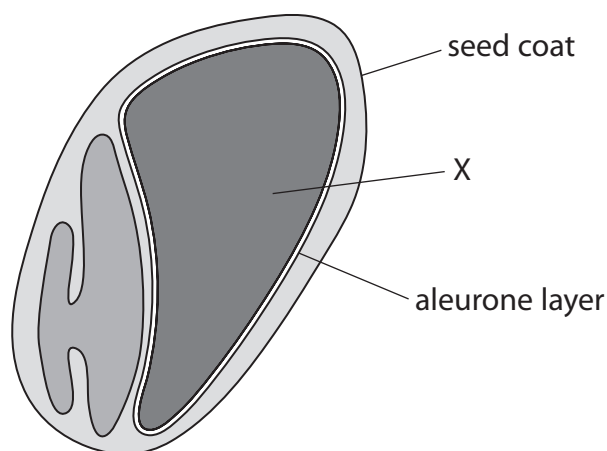
Repeat the cycle many times (e.g. 30 cycles); the DNA doubles each cycle, giving many copies.

(Total for Question 4 = 13 marks)



- 5 Gibberellin stimulates cells in the aleurone layer of cereal grains, such as barley, to produce the enzyme amylase.

The diagram shows the location of the aleurone layer in a barley grain.



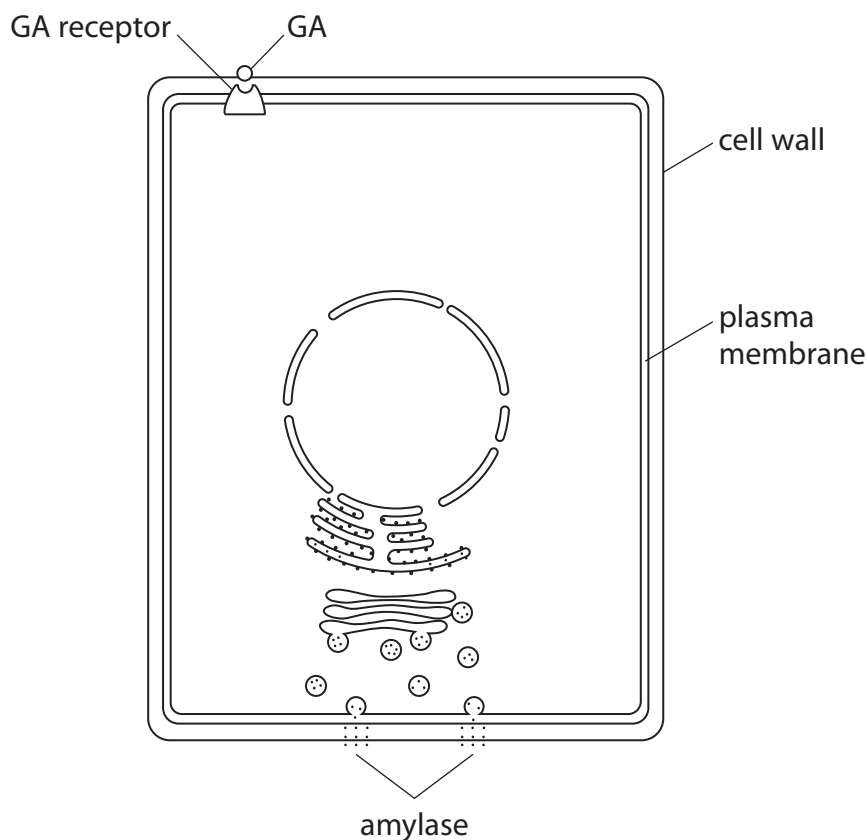
- (a) The part labelled X contains triploid cells.

Name the part labelled X.

(1)

Endosperm

- (b) The diagram shows a cell from the aleurone layer with some of the structures involved in the production of amylase.



Gibberellin binds to a protein receptor in the cell surface membrane and this stimulates transcription in the nucleus.

- (i) Describe the process of transcription in the nucleus of this cell.

(2)

The DNA strands separate (hydrogen bonds between bases break) at the gene for amylase, the antisense strand is used as a template, and RNA polymerase joins complementary RNA nucleotides to make mRNA.

- (ii) Describe the processes occurring after transcription that result in the release of amylase from the cell shown in the diagram.

(5)

The mRNA leaves the nucleus through a nuclear pore, and travels to the ribosomes on the rough endoplasmic reticulum, where translation occurs. Codons on the mRNA pair with complementary anticodons on tRNA molecules; each tRNA brings a specific amino acid to the ribosome. Peptide bonds form between adjacent amino acids, making the polypeptide (amylase), which folds in the RER. The amylase is transported in vesicles to the Golgi apparatus, where it is modified (processed) and packaged into secretory vesicles. The vesicles move to and fuse with the plasma membrane, releasing amylase from the cell by exocytosis.



- (c) Global warming may cause sea levels to rise and salty seawater to flood land used for growing crops.

A student read that salt (NaCl) inhibits gibberellin synthesis.

This could affect amylase production in cereal grains.

Devise an investigation to show the effect of salt concentration on amylase production in cereal grains.

(5)

Soak barley grains in a range of at least five salt (NaCl) concentrations, e.g. 0, 0.1,

0.2, 0.3, 0.4 and 0.5 mol dm⁻³, for the same time; 0 (distilled water) is the control.

Surface sterilise the grains (wash in dilute bleach, then rinse) and use sterile starch agar in sterile Petri dishes, so microorganisms do not digest the starch.

Cut the grains in half (remove the embryo half if gibberellin is to be added) and place the same number of cut grains, cut surface down, onto starch agar.

Leave the dishes for 24 to 48 hours at the same temperature (e.g. 25 °C in an incubator).

Remove the grains and flood the agar with iodine solution: starch stains blue-black, while areas where amylase has digested the starch stay clear.

Measure the diameter of the clear zone around each grain and calculate its area (πr^2); a larger clear zone means more amylase was produced.

Use at least 5 grains per concentration, calculate the mean and standard deviation, and plot the area of clear zone against salt concentration.

(Total for Question 5 = 13 marks)



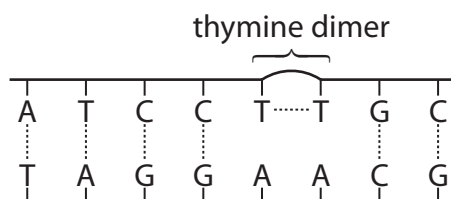
- 6 Ultraviolet (UV) radiation damages DNA and is used in microbiology to produce aseptic conditions.

The UV radiation changes the bonding found in DNA.

This change in bonding creates thymine dimers in which covalent bonds form between adjacent thymine nucleotides.

Thymine dimers bend the DNA backbone. This prevents replication of DNA.

The diagram shows the change in bonding caused by UV radiation.



- (a) Name the bonds that are lost when thymine dimers are formed.

(1)

Hydrogen bonds (between thymine and adenine)

- (b) Explain why preventing the replication of DNA produces aseptic conditions.

(2)

Bacteria (microorganisms) cannot reproduce by binary fission, so they cannot multiply on the equipment or culture,

because the DNA cannot be copied: complementary base pairing cannot occur (T cannot pair with A), and transcription (mRNA synthesis) is also prevented.



- (c) Aseptic conditions are used when growing bacteria in laboratories.

Justify two methods, other than UV radiation, for ensuring aseptic conditions.

(2)

Sterilise apparatus such as the inoculating loop by flaming it in a Bunsen burner (and autoclave the agar and Petri dishes), to kill bacteria and spores on them.

Work near a Bunsen flame, which creates an updraft that prevents bacteria in the air settling on the plate; also open the lid of the Petri dish only slightly, to prevent access by bacteria.

- (d) The effectiveness of UV radiation was investigated, using three species of pathogenic bacteria.

The table provides information about the bacteria used in this investigation.

Bacteria	Gram staining	Infected part of body
<i>P. aeruginosa</i>	negative	blood
<i>S. aureus</i>	positive	lung
<i>E. coli</i>	negative	intestine

- (i) Compare and contrast the structure of the wall of Gram positive bacteria and Gram negative bacteria.

(3)

Similarity: both have a cell wall made of peptidoglycan.

Differences: Gram positive bacteria have a much thicker layer of peptidoglycan (thicker wall) and contain teichoic acid, which Gram negative bacteria do not.

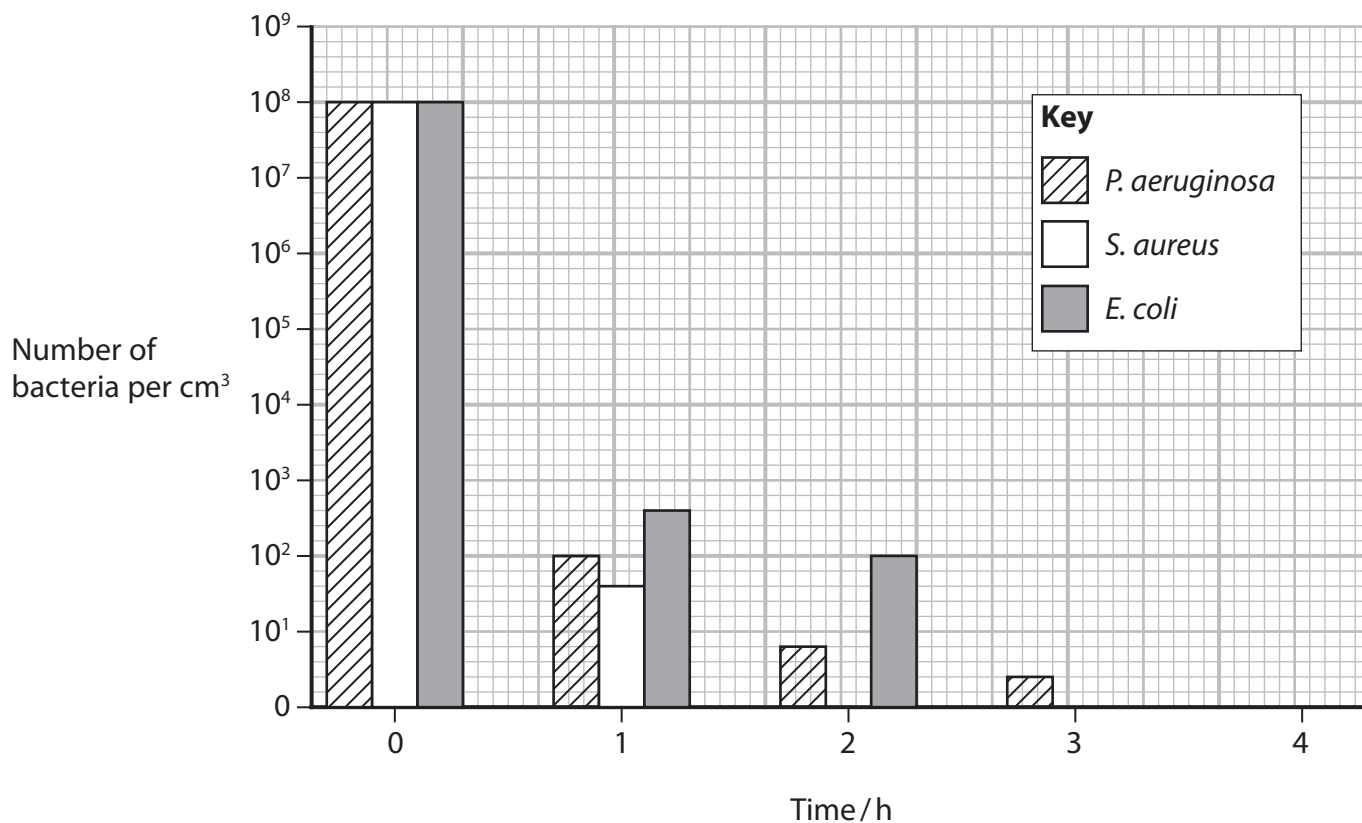
Gram negative bacteria have an outer membrane containing lipopolysaccharide (lipid) and porin proteins, and a periplasmic space, which Gram positive bacteria do not have.



- (ii) In this investigation, living bacteria of each species were exposed to UV radiation for four hours.

The numbers of living bacteria were counted each hour during the four-hour period.

The graph shows the results of this investigation.



Calculate the percentage change in numbers of living *E. coli* after two hours of exposure to UV radiation.

(2)

$$\text{at } 0 \text{ h} = 10^8 \text{ per cm}^3; \text{ at } 2 \text{ h} = 10^2 \text{ per cm}^3$$

$$\text{change} = 10^2 - 10^8 = -99\,999\,900$$

$$(-99\,999\,900 \div 10^8) \times 100 = -99.9999\%$$

Answer -99.9999 %

DO NOT WRITE IN THIS AREA

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- (iii) A student concluded from this investigation that if food is exposed to UV radiation, it would remove all risk of food poisoning.

Criticise the validity of this conclusion.

(4)

The conclusion is not valid. UV is only effective if the food is irradiated for long enough: after 1 to 2 hours some bacteria were still alive, and all were killed only after 3 to 4 hours.

It was effective against *E. coli*, which infects the intestine (food poisoning), but only three species of bacteria were investigated; not all the pathogenic bacteria that cause food poisoning (e.g. *Salmonella*, viruses) were tested.

Toxins already produced by the bacteria may remain in the food, so it could still cause food poisoning; and UV may not penetrate below the surface of the food, as this was not tested on food.

(Total for Question 6 = 14 marks)



7 The photograph shows a wood mouse, *Apodemus sylvaticus*.



(Source: © Eric Isselee/Shutterstock)

A scientist measured the population size of these mice living in a woodland habitat.

The scientist used the capture-mark-recapture method (CMR) to sample the population.

This is the CMR method used by the scientist:

- randomly place mammal traps in the woodland for one day
- put a coloured band on a leg of each captured mouse (S1)
- release these marked mice
- after one week place mammal traps in the woodland again for one day
- count the number of mice captured (S2)
- count the number of mice with leg bands in this second sample (L).

The table shows some of the results.

Number of mice captured	
S1	S2
200	250



- (a) The scientist calculated that the number of mice in the woodland was 1000, using the formula

$$\text{number of mice} = \frac{S1 \times S2}{L}$$

Determine the number of mice that had leg bands (L) in the second sample.

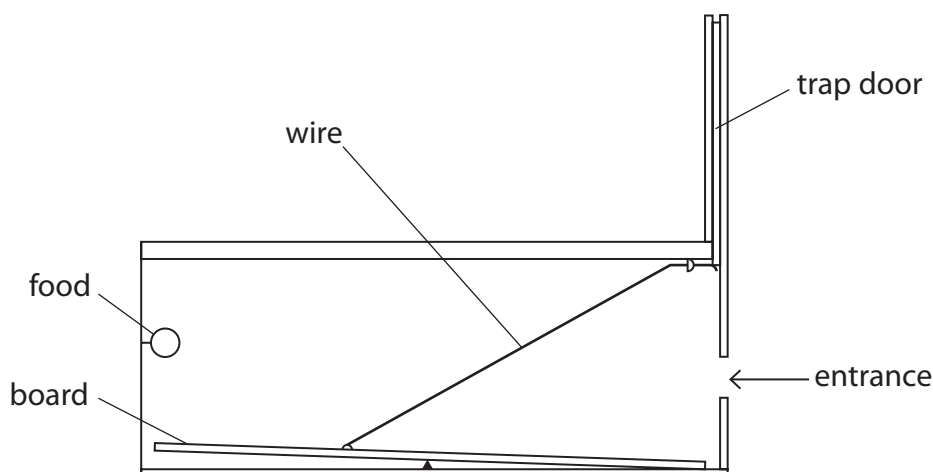
(1)

$$1000 = (200 \times 250) \div L$$

$$L = 50\,000 \div 1000$$

Answer 50

- (b) The diagram shows a section of the trap used by the scientist.



Explain how the design of the trap is effective for capturing mice.

(3)

Food at the back of the trap attracts a mouse into the trap.

The small entrance (size of the trap) allows small animals such as mice to enter but larger animals cannot.

When the mouse walks on the board towards the food, the board tilts and pulls the wire, so the trap door slides down, trapping the mouse.



(c) Wood mice are small mammals.

They cannot maintain their body temperature and will die if left in the trap for a long period of time.

Explain why wood mice cannot maintain their body temperature if left in the trap.

(4)

Mice are small, so they have a large surface area to volume ratio,

so they lose a lot of heat quickly to the surroundings.

Heat is generated by metabolism (respiration), so they need a high metabolic rate to maintain body temperature,

and if they are left in the trap there is insufficient food to maintain this high metabolic rate (release enough energy).

There is no bedding (nest material) in the trap for insulation to prevent heat loss.



(d) Comment on the claim that the CMR method produces an accurate measure of the population size of mice in the woodland.

(5)

The method may not be accurate: births and deaths may occur during the week

between samples, changing the population size.

Migration (immigration or emigration) of mice into or out of the woodland may occur.

Marking may affect survival, e.g. a coloured band may make mice more visible to

predators, or mice may lose their bands, so L is too small and the population is

overestimated.

Food in the trap encourages capture (trap-happy mice), or some mice may avoid the

trap after being caught (trap-shy), so some mice are more likely to be caught than

others.

However, it may be accurate because one week is long enough for the marked mice to

disperse randomly through the population,

the traps were randomly placed, which avoids bias, and the sample sizes were large

(200 and 250 mice), so the estimate of 1000 is likely to be reliable.

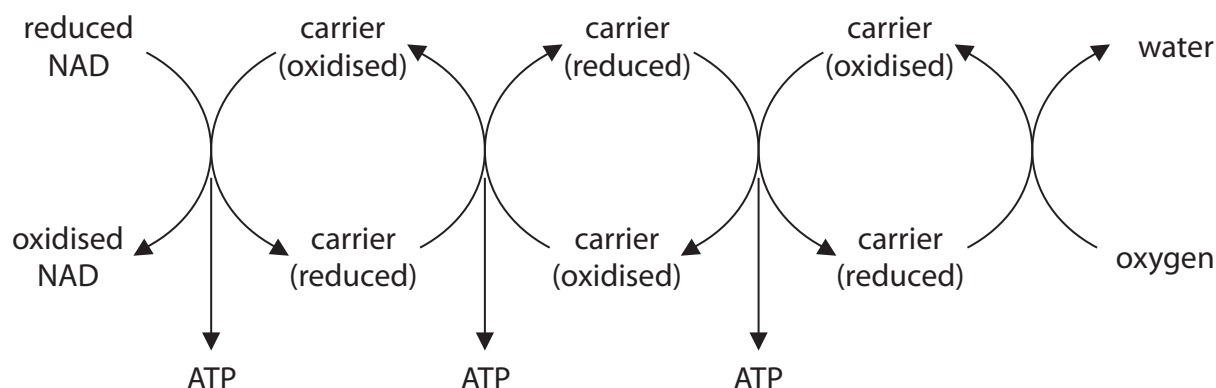
(Total for Question 7 = 13 marks)



P 6 2 1 2 7 A 0 2 3 3 6

8 The electron transport chain generates ATP.

The diagram shows the electron transport chain.



(a) State the location of the electron transport chain in a mitochondrion.

(1)

Inner mitochondrial membrane (cristae)

(b) Hydrogen cyanide gas is a poison that can kill an animal if it is inhaled.

Cyanide is a non-competitive inhibitor of the enzyme cytochrome oxidase.

Cytochrome oxidase is the last carrier in the electron transport chain.

(i) Explain why hydrogen cyanide gas can kill an animal.

(5)

Cyanide binds to cytochrome oxidase away from the active site, changing its tertiary structure and the shape of the active site, so the substrate no longer fits.

So the transport of electrons (and hydrogen ions) along the electron transport chain stops: the carriers cannot be reoxidised, so the earlier carriers cannot be reduced, and oxygen is no longer the final electron acceptor.

So no ATP is made by oxidative phosphorylation (less ATP is made).

Without ATP, muscles cannot contract, so breathing stops and the heart stops; other processes that require ATP, such as active transport, also stop, so cells die.



(ii) A dose of 1.0 mg of hydrogen cyanide per kilogram of body mass is fatal.

An animal with a body mass of 10 kg inhaled air containing 0.24 mg dm^{-3} of hydrogen cyanide.

The animal breathed at a rate of 15 dm^3 of air per minute.

Calculate how many minutes it would take for this animal to obtain a fatal dose.

Give your answer to three significant figures.

(3)

$$\text{fatal dose} = 1.0 \times 10 = 10 \text{ mg}$$

$$\text{mass inhaled per minute} = 0.24 \times 15 = 3.6 \text{ mg min}^{-1}$$

$$\text{time} = 10 \div 3.6 = 2.777... \text{ minutes}$$

Answer 2.78..... minutes

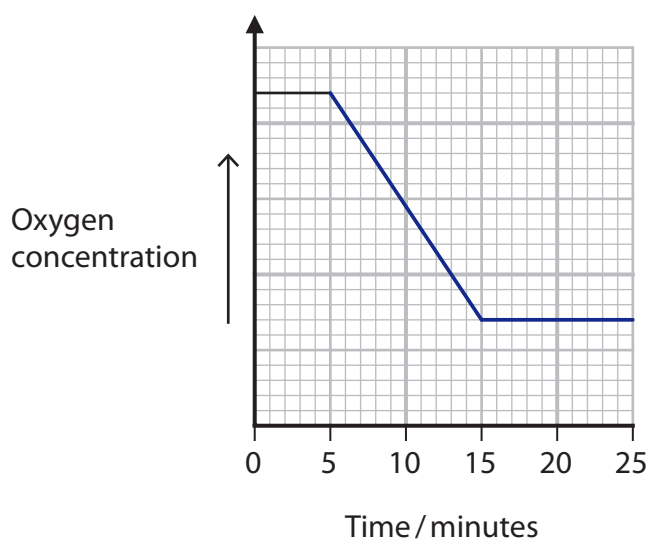
(c) The effect of cyanide on oxygen uptake by mitochondria was investigated using the following method:

- suspend mitochondria in a flask containing a buffer solution
- measure the concentration of oxygen in the flask for the first five minutes
- then add a respiratory substrate and ADP to the flask
- measure the concentration of oxygen in the flask for the next 10 minutes
- then add cyanide solution to the flask
- measure the concentration of oxygen in the flask for the next 10 minutes.

The graph shows the results for the first five minutes.

Complete the graph to show the results for the next 20 minutes.

(2)



(Total for Question 8 = 11 marks)



9 Biodiversity is monitored by conservationists.

Biodiversity can be calculated using the formula

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

- (a) Give the symbol in this formula that represents the total number of organisms of all species.

(1)

N

- (b) The photograph shows a hedge.



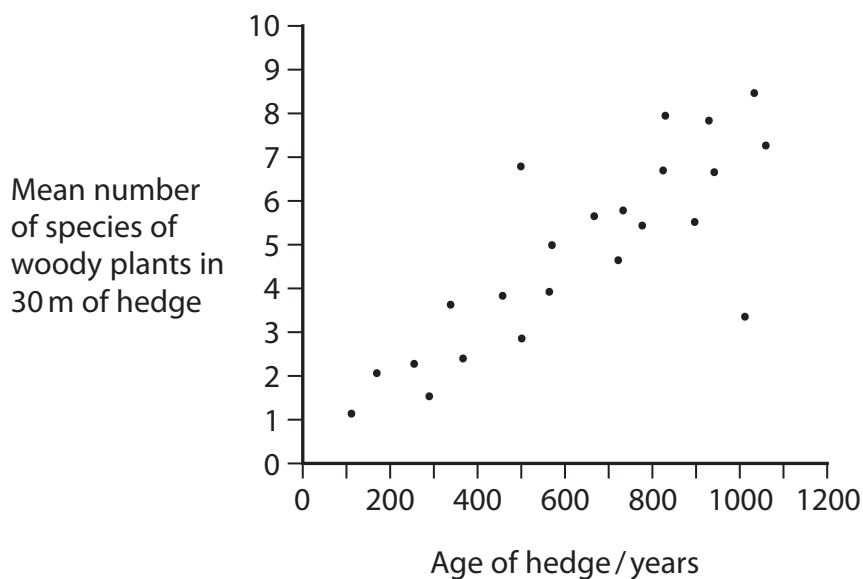
(Source: © 1000 Words/Shutterstock)

Many fields in the UK are separated by hedges.

Conservationists investigated biodiversity in hedges of different ages.

Hedges of different ages were sampled at random and the number of species of woody plants was counted.

The graph shows the results of this investigation.



Analyse the data to explain why conservationists object to the destruction of hedgerows to increase the size of fields.

(4)

There is a positive correlation: the mean number of species of woody plants increases with the age of the hedge, from about 1 species at 100 years to about 8 species in hedges over 800 years old.

So old hedges have high biodiversity; if they were destroyed many species would be lost, and it would take hundreds of years for new hedges to reach the same biodiversity.

Older hedges provide more niches, so more species of animals (invertebrates and vertebrates) are associated with them,

as hedges provide shelter, food and nesting sites, and act as corridors allowing safe movement of animals between habitats (interbreeding, maintaining genetic variation).

(c) State why random sampling was used in this investigation.

(1)

To avoid bias, so that the sample is representative of all the hedges.



- (d) The conservationists observed that the plants in older hedges contained more wood than the plants in younger hedges.

Wood consists of xylem tissue.

- (i) Give an advantage for older plants of containing more wood.

(1)

The stems are stronger and better supported (less likely to break), and more water and mineral ions can be transported.

- (ii) Describe a method to show that the stem of an older plant contains more wood.

(3)

Cut thin cross sections of the stem from the same height in young and old plants, stain them with a named stain (e.g. phloroglucinol or toluidine blue) to show the lignified xylem, and measure the thickness (area) of xylem tissue using a microscope with an eyepiece graticule.



- (e) A student thought that the age of a plant affects the water potential of its tissue.

The student used potatoes of different ages to test this hypothesis.

Justify each step of a method the student could use to compare the water potential of potato tissue of different ages.

(5)

Use a cork borer to cut potato cylinders of the same diameter and cut them to the same length, so they have the same surface area to volume ratio, which affects the rate of osmosis.

Place cylinders into a range of sucrose solutions (e.g. 0 to 1.0 mol dm⁻³) so water can enter or leave the tissue by osmosis.

Use the same variety of potato and leave them for the same time (e.g. 24 hours) at the same temperature, as these affect the rate of osmosis.

Blot the cylinders with a paper towel to remove surface water before weighing, so only water inside the tissue is measured.

Measure the initial and final mass and calculate the percentage change in mass, to allow for different starting masses, and plot a graph against sucrose concentration.

Where the line crosses the x axis there is no change in mass, which gives the concentration with the same water potential as the tissue.

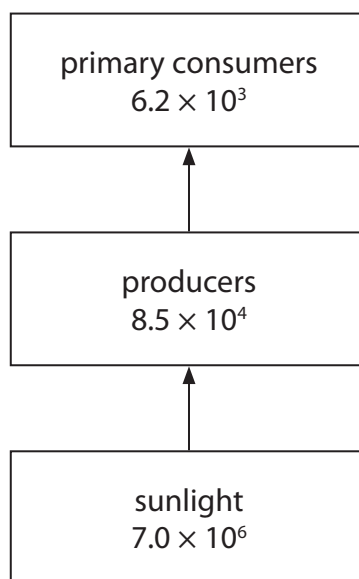
Repeat for potatoes of different ages and compare the values where the lines cross the x axis.

(Total for Question 9 = 15 marks)



10 The diagram shows the flow of energy in an ecosystem.

The numbers represent the energy in $\text{kJ m}^{-2} \text{yr}^{-1}$ in each category.



- (a) (i) Calculate the percentage efficiency of energy transfer from sunlight to the producers. (2)

$$(8.5 \times 10^4 \div 7.0 \times 10^6) \times 100$$

$$= (85\,000 \div 7\,000\,000) \times 100 = 1.214$$

Answer 1.21 %

- (ii) Give one reason why the energy transfer from sunlight to the producers is less than 100% efficient. (1)

Some light is reflected from the leaves or misses the chlorophyll (only certain wavelengths are absorbed).



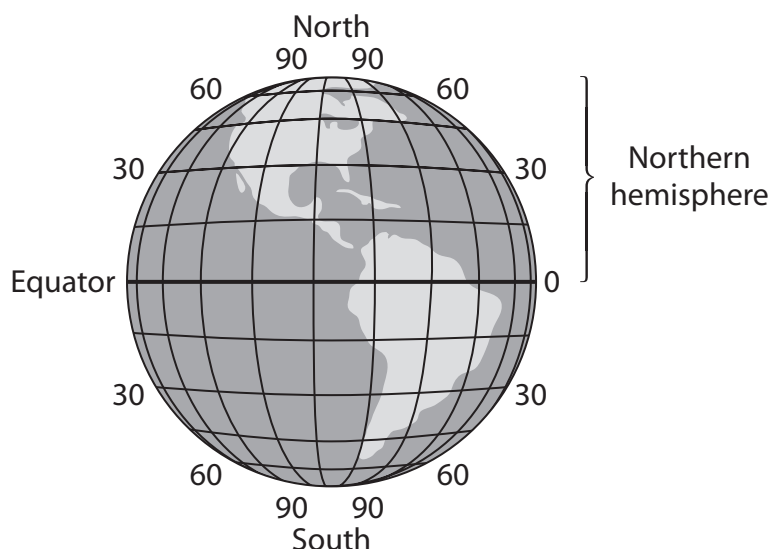
(iii) Explain the energy difference between the producers and the primary consumers. (2)

Some of the producers are not eaten, and some parts are not digested (lost in faeces), e.g. cellulose and lignin.

Energy is lost from the producers by respiration, as heat, so it is not available to the primary consumers.

(b) Plant productivity is affected by the abiotic and biotic factors that exist at different latitudes.

The diagram shows latitudes of the Earth.



The table shows the productivity of plants growing on land at different latitudes in the Northern hemisphere.

Latitude / degrees	Productivity / $\text{g m}^{-2} \text{yr}^{-1}$
0 to 10 (equatorial conditions)	900 to 1500
30 to 40 (warm temperate conditions)	400 to 800
40 to 60 (cool temperate conditions)	200 to 600
60 to 70 (alpine to arctic conditions)	0 to 200



A student concluded that primary productivity is determined by abiotic factors that affect the light-dependent and light-independent stages of photosynthesis.

Discuss the validity of this conclusion.

(9)

The conclusion is partly valid. Light is an abiotic factor: there is more light (higher light intensity and longer growing season) at the equator and less at higher latitudes, which matches the highest productivity (900 to $1500 \text{ g m}^{-2} \text{ yr}^{-1}$) at 0 to 10 degrees and the lowest (0 to 200) at 60 to 70 degrees.

In the light-dependent stage, light excites electrons in chlorophyll, photolysis of water occurs, and ATP (photophosphorylation) and reduced NADP (NADPH) are made. More light means more ATP and reduced NADP.

In the light-independent stage (Calvin cycle), carbon dioxide is fixed by RUBISCO to form GP, which is reduced to GALP using ATP and reduced NADP, and then used to make glucose and other organic molecules, so more biomass is produced.

Temperature is also an abiotic factor: it is higher at the equator and lower at high latitudes. Temperature affects enzymes such as RUBISCO, so the Calvin cycle is slower in the cold; it also affects active uptake of mineral ions and the rate of transpiration.

However, other abiotic factors also affect productivity. Carbon dioxide is unlikely to be limiting as its concentration is similar at all latitudes. Lack of water (e.g. deserts or frozen water in polar regions) limits productivity, since water is needed for photolysis and mineral ion transport. Mineral ions such as nitrate (for amino acids and proteins) and magnesium (for chlorophyll) depend on soil (edaphic) factors and pH.

Biotic factors also affect productivity: disease (pathogens such as fungi), grazing by herbivores and pests, and competition for light. Decomposition is slower at high latitudes, so fewer mineral ions are released.

Human factors such as deforestation, crop planting, fertiliser and pesticide use also change productivity.



The data have limitations: the ranges overlap, e.g. cool temperate (200 to 600) can exceed warm temperate (400 to 800), the latitude bands are of unequal size, the data are only for land in the Northern hemisphere and productivity in the oceans is not taken into account.

Productivity is subject to limiting factors, and many abiotic and biotic factors interact, so the conclusion that productivity is determined only by abiotic factors affecting photosynthesis is not fully valid.

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 120 MARKS



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